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APPLICATION OF US-SCS CURVE NUMBER METHOD AND GIS FOR DETERMINING SUITABLE LAND COVER OF SMALL WATERSHED

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ABSTRACT

This study aims to reveal the appropriate land cover which can reduce run-off using US-SCS Curve Number method with GIS. Four land cover scenarios are developed to reveal which one of existing land cover types is appropriate for the area. To make a validation of the application US-SCS Curve Number Method, calculating observational run-off is required. Statistical analysis is than used to test those two run-off data. The result of this study shows that actual run-off depth is 2143, 0 mm and peak discharge is 91, 76 m³/s. The result also reveals that forest coverage can reduce dramatically surface run-off until 48, 38 percent. Potato increases surface run-off 1, 59 percent, on the contrary, applying cacica papaya can reduce surface run-off 24, 6 percent. Scenario 4 is developed based on the result of the previous scenario on run-off yield. Run-off yield result from scenario 4 is 1690, 40 mm (decrease 21, 14 percent from actual run-off). Statistical analysis shows that there is no difference between observed run-off depth and estimated run-off depth in the level of significance 5 %.

Keywords: US-SCS curve number method, GIS, suitable land cover

INTRODUCTION

Some parts of Indonesia suffer from natural hazards associated with high intensity of rainfall event, such as flood and erosion. The phenomenon of natural disasters which often happens in current days is an indication of land degradation in some areas. Land degradation caused by various things. The main cause of land degradation is the increasing number of population. This population growth is not equal with the availability of land for settlement. On the other hand, increasing population also leads to increase the need of agriculture area [*Trimurti*, 2010]. This encourages people to exploit natural resources (forest logging) and convert forest land to agriculture and settlement.

Some studies have shown that changes in land use or land treatment lead to changes in amount of rainfall which change into run-off [*Arysad,* 1989]. Land conversion from forest coverage into non forest coverage impact on hydrological condition of the area. High amount of run-off triggers much natural disaster in rainy season.

In the last twenty years, Pakuwojo Sub-Watershed (in upper part of Serayu Watershed) experienced rapid changes in its physical condition. Before the year of 1980, upper of Serayu Watershed are mostly covered by forest. Vegetable plantation, such as potato, cabbage etc, began to be known by local people in 1983. This condition brings negative impact on hydrological condition of the area. Existing land use types, hydrologic ally, result in high amount of surface run-off as watershed respond to rainfall events. High amount of surface run-off triggers natural disaster, such as flood and erosion, in down stream. Suitable land cover in which can reduce surface run-off is needed to improve hydrological regime in study area.

US-SCS curve number method combining with Geographic Information System (GIS) technique is widely used to estimate run-off depth. Many studies concluded that GIS is an efficient tool for data preparation required by the US-SCS Curve Number method. Land use/land cover is an important parameter input of the US-SCS Curve Number method. Modification on land cover can be done using this method to determine suitable land cover for the study area.

The study area, named Pakuwojo Sub-Watershed, is located in upper part of Serayu Watershed, Wonosobo Regency, and Central Java, Indonesia. The total sub-watershed area is approximately 132, 60 ha. Geographically, it stretches between latitude 7°13'43''S to 7°14'20" S and longitude 109°55'22'' E to 109°56'20'' E. Geologically, Pakuwojo Sub-Watershed comprises two formation, Dieng volcanic and Jambangan volcanic. Landform formation of the study area is mostly as a result of volcanic activities. Landform of volcanic cone slightly dissected and volcanic foot slope slightly dissected covers mostly of Pakuwojo Sub-Watershed. Fig.1 present Paku wojo Sub-Watershed area based on its administrative boundaries.

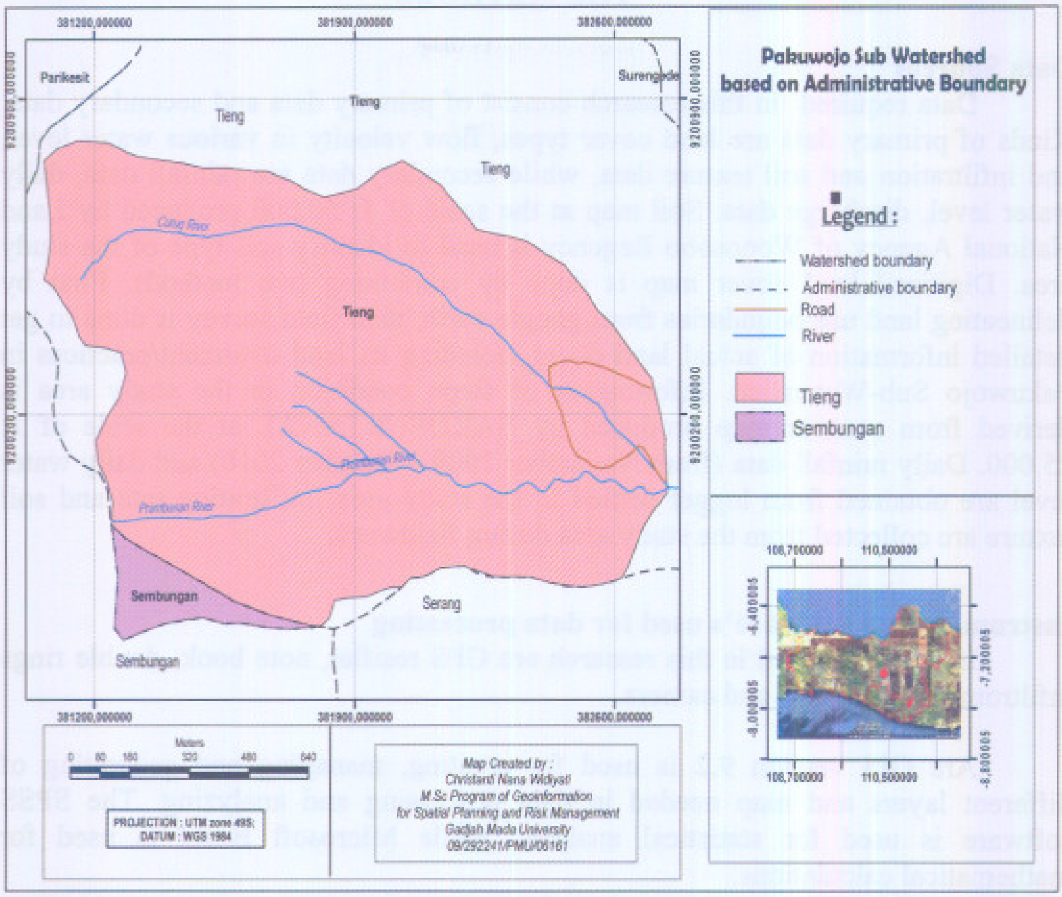

Figure 1. Administrative map of pakuwojo Sub-Watershed

Two soil types are found in Pakuwojo Sub-Watershed. Soil type in the western area of the watershed is association of Brown Andosol and Brown Regosol, whereas the soil type in the eastern area is Organosol Eutotrof.

The relief of Pakuwojo Sub-Watershed is varying, from flat to steep and almost 45 % of the watershed area is located in extremely steep area.

THE METHODS

Data Sources

Data required in this research consist of primary data and secondary data. Kinds of primary data are land cover types, flow velocity in various water level, and infiltration and soil texture data, while secondary data are rainfall data, daily water level, discharge data. Soil map at the scale of 1: 50.000 produced by Land National Agency of Wonosobo Regency is used to identify soil type of the study area. Digitized land cover map is done by combining two methods. First by delineating land use boundaries from google earth, then field survey is done to get detailed information of actual land cover including its land treatment/practices in Pakuwojo Sub-Watershed. Information of slope condition in the study area is derived from contour map produced by BAKOSURTANAL at the scale of 1: 25.000. Daily rainfall data (from November 2009 – October 2010) and daily water level are obtained from logger settled in the study area. Infiltration rate and soil texture are collected from the study area during fieldwork.

Instrument and software's used for data processing

Instruments used in this research are GPS resifier, note book, double rings infiltrometer, compass, and camera.

Arc GIS version 9.2 is used for creating, managing and generating of different layers and map needed in data processing and analyzing. The SPSS software is used for statistical analysis, while Microsoft Excel is used for mathematical calculations.

Methodology

Data collecting is done by combining two methods, remote sensing technique for boundaries delineation of each land use type and field survey for determining land cover types and its land treatment. Field survey is also conducted for other data collecting (soil texture, soil infiltration and river flow velocity).

Identification of actual land use and land cover

Detailed information of land use in the study area is obtained by combining two methods. First by delineating land use boundaries from google earth, then field survey is done to get detailed information of actual land cover including its land treatment/practices in Pakuwojo Sub-Watershed.

Generating Hydrologic Soil Group (HSGs) Map

Hydrological soil group map is generated by imputing infiltration rate of each land unit to land mapping unit. Hydrological soil groups used in this study are hydrological soil groups from US-SCS as presented on Table 2 US-SCS divided soil into four groups based on its infiltration rate and soil texture. The generated map consists of individual polygons of the characterized hydrologic soil group.

Table 2. Hydrological soil groups

HSG	Explanation	Infiltration rate (cm/hour)	Soil texture
Group A	Soils having high infiltration rates when thoroughly wetted and a high rate of water transmission. Examples are deep, well to excessively drained sands or gravels.	8 – 12	Sand, loamy sand, sandy loam
Group B	Soils having moderate infiltration rates thoroughly wetted and a moderate rate of water transmission. Examples are moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures	4 – 8	Silt loam, loam
Group C	Soils having low infiltration rates when thoroughly wetted and a low rate of water transmission. Examples are soils with a lays that impedes the downward movement of water or soils of moderately fine to fine texture.	1 - 4	Sandy clay, loam
Group D	Soils having very low infiltration rates when thoroughly wetted and a very low rate of water transmission. Examples are clay soils with a high swelling potential, soils with a permanently high water Table, soils with a clay pan or clay layer at or near the surface, or shallow soils over nearly impervious material.	0 - 1	Clay loam, salty clay, loam, sandy clay, salty clay, clay

Source: Anonym, 2004 and Asdak, 2007

Generating Curve Numbers (CN) Map

Curve number map is generated by overlying (intersection) the hydrological soil group map and land cover map. Before uploaded to GIS software, actual land cover of the study area has to be reclassified based on land cover classification of US-SCS. Parameters taken into account in US-SCS land use reclassification are classification of cultivated area, land treatment/practices, and hydrological condition. The result of intersection between reclassified land use map and hydrological soil group map is a new polygon that representing the merged between soil hydrologic group and land use map. The appropriate CN value from US-SCS can be assigned.

Antecedent Moisture Condition (AMC) Class

The condition of soil moisture before run-off occurs is one parameter have to be considered in determining final value of curve numbers in the area. This moisture condition is called Antecedent Moisture Condition (AMC). The calculated CN value for each polygon is for Antecedent Moisture Condition Class II (average condition). Antecedent Moisture Condition is divided into three classes and each class is generated in the basis of 5-day antecedent rainfall on the watershed. To determine which Antecedent Moisture Class is agreeing with the area, daily rainfall data is needed. Table 3.2 below presents the value of rainfall limit of each AMC Class.

Table 3. Rainfall limit for AMC Classes based on US-SCS Method

AMC Class	Description	5-day antecedent rainfall (mm)
I	The soil in drainage basin are practically dry	< 23
II	Average condition	23 – 40
III	The soil in the drainage basins are practically saturated	> 40

Source: Anonym, 2004

Estimating run-off depth

After CN map with appropriate AMC Class is generated, run-off depth of the study area could be calculated by using the equation developed by US SCS.

$$Q = \frac{(P - Ia)^2}{P - Ia + S}\text{, with } I_a = 0,2\,S$$

$$S_{(mm)} = \frac{25400}{\text{weighted CN}} - 254$$

Where:

Q (mm) : Accumulated run-off depth
P (mm) : Accumulated rainfall
I (mm) : Initial abstraction
S (mm) : Potential Maximum Retention

Estimating peak discharge and the time distribution of the direct run-off

In this part, estimation of peak discharge and time distribution of the direct run-off is employed using the concept of unit hydrograph. This method is commonly used in the ungauge watershed where no run-off has been measured.

US-SCS developed formulas using empirical coefficient within connect unit hydrograph elements and physical characteristics of watershed. Element of unit hydrograph are lag time, time to peak, peak discharge and base time. Physical characteristic of watershed are watershed area (A), maximum length of travel (L), and slope of the watershed (S). Equations developed by the HSS-US SCS to calculate peak discharge is presented below [*Anonym*, 2004].

$$qp = 0,2008 \frac{AQ}{Tp}$$

where $Tp = 0,7Tc$

(qp is peak discharge of unit hydrograph (m^3/s), A is watershed area (sq.km), Q is run-off depth, tp is time to peak (hour), and Tc is time of concentration)

Time of concentration can be described as the time of run-off to travel from the most remote point of the watershed to its outlet.

The following formula explains the way how to obtain time of concentration (Tc).

$$Tc = 0,02L^{0,77}S^{-0,385}$$

(Tc = time of concentration (minute), L = maximum length of travel (m), S = slope. Slope is obtained by divided H/L, H is the elevation difference between the most remote point in the watershed and the outlet)

Generating land cover scenarios

Some land cover scenarios are developed to identify the catchments response to land cover change on run-off yield. These scenarios is useful to determine which land cover type should be improved to meet better hydrological condition in the study area.

Four scenarios are developed in the study area. Scenario 1, 2, 3 are developed to reveal the impact of some main existing land cover types on run-off yield. Three land cover types, forest, potato, and carica papaya, are investigated its impact on run-off yield. Forest is estimated as the best cover types in term of reducing run-off yield. Potato is estimated as the highest contributor on run-off yield. Carica papaya is alternative commodity which can substitute potato. The comparation of its impact on run-off yield among those vegetations would be known by applying into the models/scenarios.

More rational and acceptable scenario for local people is applied in scenario 4. This scenario is developed based on the result of the previous scenarios on run-off yield. This scenario consists of five types of land coverage i.e forest, settlement, potato, and carica papaya and mix garden). An expansion on forest and carica papaya coverage in this scenario is expected will bring better condition on hydrological regime in the area. In this scenario, local people still can have some areas for vegetable plantation (potato and mix garden) for daily needed or for commercial. This scenario is expected can reduce run-off yield in the study area.

Comparing and analyzing the effect on run-off between actual land cover and applying land cover models

After applying land cover scenarios for the area, estimated run-off of an applying land cover models are compared to estimate actual land cover run-off. The model that can reduced run-off significantly is proposed as the best land cover for the study area.

Observed run-off depth of Pakuwojo Sub-Watershed

In order to verify the result of run-off estimation using US-SCS Curve Number method, an observational run-off data is required to make a comparation between them. Observational run-off data is obtained from field data analysis. Main data needed to measure observational run-off are river discharge (in m^3/second) and water level data.

- Water level data (m)
  Water level data are obtained from the field using logger which settled in the river outlet. This tool notes water level alteration each ten minus.
- Flow velocity in various water level (m/second)
  Flow velocity in various water levels is measured using current meter
- Discharge data (m^3/second)
  Discharge data is obtained by multiplying flow velocity in various water level (in m/second) and river cross section (in m^2). Discharge data and water level are used to generate rating curve "river discharge – water level". The more flow velocity is measured, the better data will be obtained.
  The equation result from rating curve then can be used to calculate river discharge in various water levels obtained from logger.

River discharge consists of base flow and direct run-off. Separation process is then needed to get direct run-off in various rainfall events. Method used to separate river discharge into its base flow and direct run-off is Straight Line method [*Seyhan,* 1995]. This is done by making a linear line, start from the decline of the hydrograph until the the change of slope. The slope change point is obtained by plotting discharge data and observation time into the graph. Base on hydrograph separation result, run-off volume could be calculated. Run-off depth is then determined by dividing run-off volume with the watershed area.

Validation for the application of Curve Number Method in the Study Area

The result of run-off estimation using curve number method from US-SCS will be compare with the run-off observation result from field data analysis. Run-off observation result from field data analysis is recognized as "true" value of run-off depth. This is done to examine the suitability of US-SCS Curve Number method for run-off estimation in the study area.

Statistical test, student's t distribution test (t-test), will be used to investigate the suitability for the application of US-SCS Curve Number Method in the study area. Statistical analysis is conducted using SPSS software.
Some statistic equations used in this statistical test are:

$$\sigma = \left(\frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2}\right)^{1/2}$$

Where:
σ : *deviation standard of population*
N : *amount of samples*
S : *sample variants*

$$t = \frac{| X_1 - x_2 |}{\alpha \, (1/N_1 + 1/N_2)^{1/2}}$$

Where:
t: student's distribution
x : samples mean

If the value of "t" is less than "t_{cr}" ($t < t_{cr}$), this means that between two samples (observed run-off depth and estimated run-off dept) have no differences in the level of significantly chosen. This can be concluded that US-SCS Curve Number method is suitable to be applied in the study area for run-off depth estimation.

RESULTS AND DISCUSSION

Actual land covers of Pakuwojo Sub-Watershed

Field ground check is conducted on October 2010 to get detailed land use types and land cover type of Pakuwojo Sub-Watershed including its land treatment/practices. Table 4.1 shows the area of each land cover of Pakuwojo Sub-Watershed and Fig. 2 presents land cover map of Pakuwojo Sub-Watershed.

Table 4. Land cover and its land treatment/practices of Pakuwojo Sub-Watershed

Nr	Land use	Land treatment/practice	Area (ha)	Area Presents to Total Watershed (%)
1	Bare land	Land terraced	7,73	5,83
2	Cabbage	Land terraced	2,21	1,66
3	Cabbage	Rockwall terraced	15,64	11,80
4	Cabbage	Non terraced	2,26	1,71
5	Carica papaya	Land terraced	4,78	3,61
6	Carrot	Non terraced	0,37	0,28
7	corn	Land terraced	4,90	3,70
8	corn	Rockwall terraced	2,38	1,80
9	Forest	-	48,75	36,76
10	Mix garden	Land terraced	14,45	10,90
11	Mix garden	Rockwall terraced	5,06	3,82
12	Mix garden	Non terraced	0,15	0,11
13	Potato	Land terraced	17,60	13,28
14	Settlement	-	1,90	1,43
15	Shurub	-	1,69	1,27
16	tobacco	Land terraced	2,44	1,84
17	tobacco	Non terraced	0,29	0,22
	Total		132,60	100,00

Source: GIS computation of actual land cover map, 2010

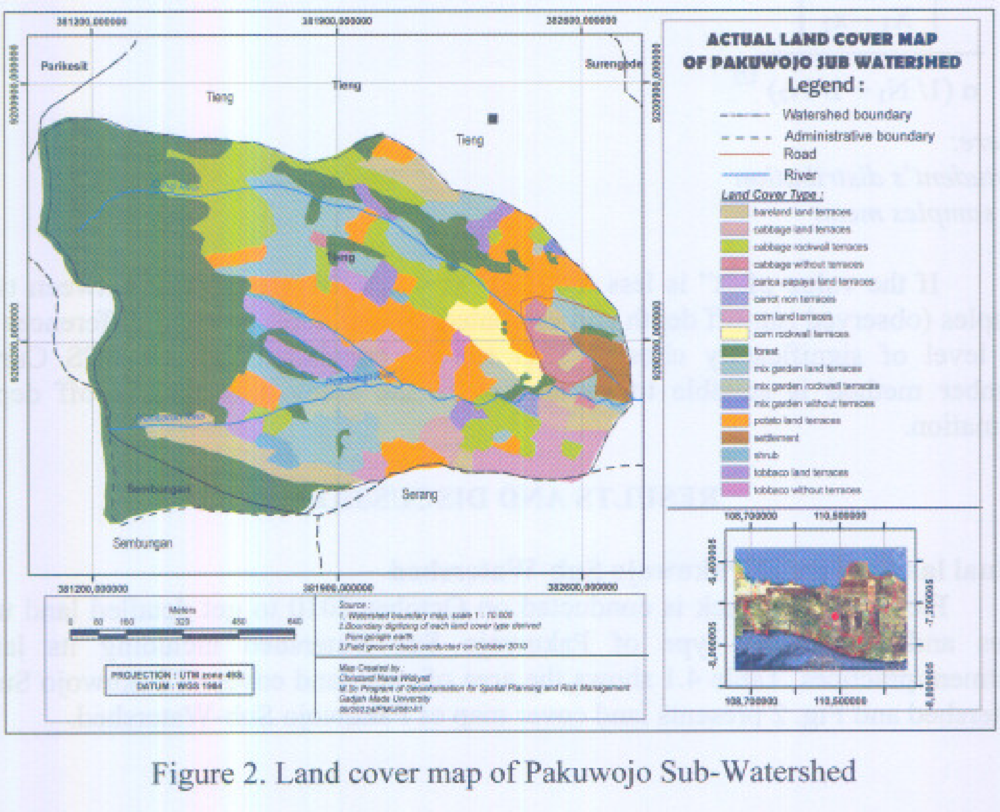

Figure 2. Land cover map of Pakuwojo Sub-Watershed

Hydrological Soil Groups map

Hydrological soil condition is generated based on infiltration rate or soil characteristic (soil texture) of each land mapping unit. Infiltration rate is obtained from each land unit using double rings infiltrometer. Hydrological Soil Group of the study area is presented in Fig. 3

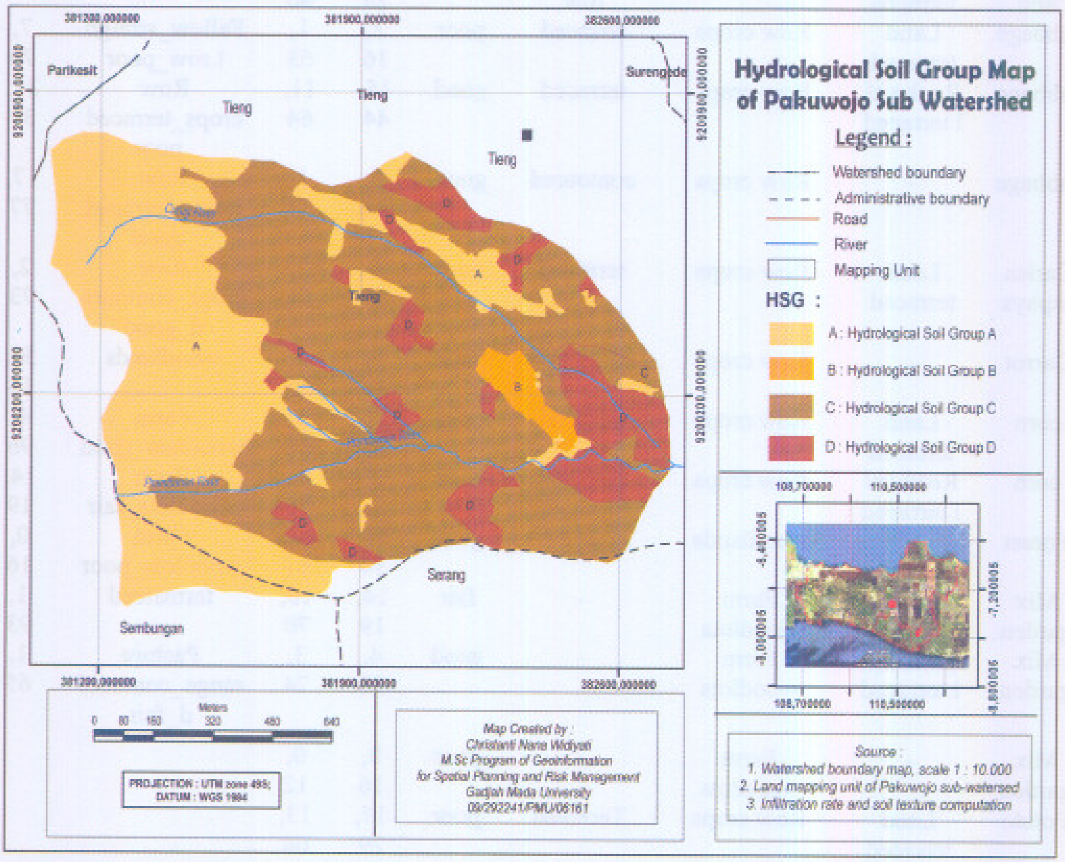

Figure 3. Hydrological Soil Group (HSG) map of Pakuwojo Sub-Watershed

Curve Number (CN) map of Pakuwojo Sub-Watershed

Main data needed to develop curve number map are hydrological soil group map and land cover map. Table 5 presents reclassified land cover of pakuwojo Sub-Watershed

Table 5. Reclassified land cover of pakuwojo sub watershed

Nr	Actual Land use/land cover		US-SCS			Area				
	Land cover	Practice	LU Classification	Practice	Class	(ha)	%	LU Classification	ha	%
1	Bare land	Land terraced	Fallow	Straight row	poor	7,70	5,80			
2	cabbage	Land terraced	Row crops	terraced	poor	2,16	1,63	Fallow_straight row_poor	7,70	5,80
3	cabbage	Rockwall terraced	Row crops	terraced	good	15,44	11,64	Row crops_terraced_poor	31,39	3,67
4	cabbage	-	Row crops	contoured	good	2,08	1,57	Row crops_terraced_good	17,77	13,40
5	Carica papaya	Land terraced	Row crops	terraced	poor	4,64	3,54	Row crops_contoured_good	2,73	2,06
6	Carrot	-	Row crops	contoured	good	0,36	0,28	woodlands	50,14	37,81
7	corn	Land terraced	Row crops	terraced	poor	4,85	3,66	Farm woodlots_good	4,96	3,74
8	corn	Rockwall terraced	Row crops	terraced	good	2,33	1,76	Farm woodlots_fair	14,19	10,70
9	Forest	-	woodlands	-	good	50,14	37,81	Farm woodlots_poor	0,16	0,12
10	Mix garden	Land terraced	Farm woodlots	-	fair	14,19	10,70	farmstead	1,93	1,46
11	Mix garden	Rockwall terraced	Farm woodlots	-	good	4,96	3,74	Pasture range_contoured_fair	1,65	1,25
12	Mix garden	-	Farm woodlots	-	poor	0,16	0,12			
13	Potato	Land terraced	Row crops	Terraced	poor	17,29	13,04			
14	Settlement	-	farmstead	-	-	1,93	1,46			
15	Shrub	Land terraced	Pasture range	contoured	fair	1,65	1,25			
16	Tobacco	Land terraced	Row crops	Terraced	poor	2,39	1,80			
17	tobacco	-	Row crops	contoured	good	0,28	0,21			
						132,60	100,00		132,60	100,00

Source: GIS computation of Reclassified Land Cover Map of Pakuwojo Sub-Watershed

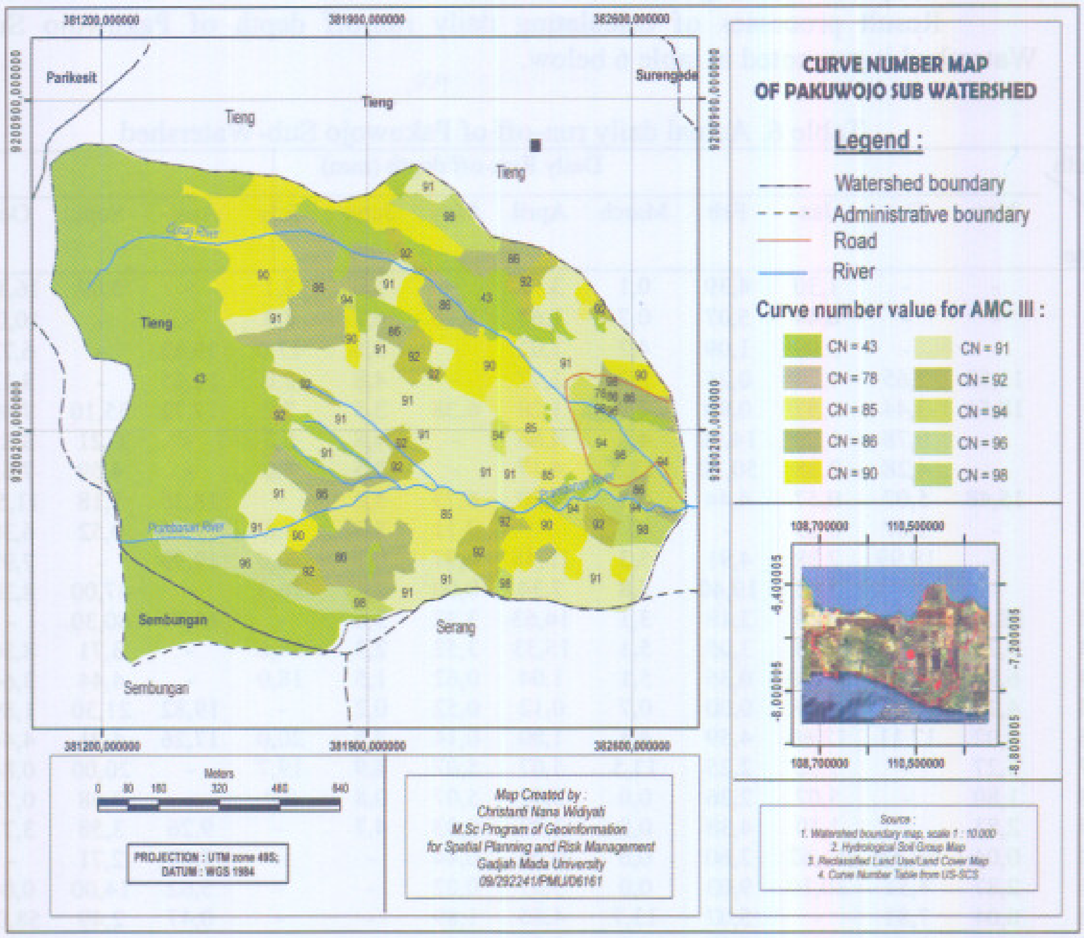

Figure 4. Curve number map of Pakuwojo Sub-Watershed

After reclassified land use is obtained, the next step is determining Curve Number (CN) of Antecedent Moisture Class II. This was done by intersected Hydrological Soil map (HSG) and Reclassified Land Cover. The generated map as shown in Fig. 4 consist of new polygons representing the merged of soil hydrologic group and reclassified land use.

Antecedent Moisture Condition (AMC)

Antecedent Moisture Condition (AMC) is calculated everyday based on 5-day antecedent rainfall (i.e. the accumulated total rainfall preceding the run-off under consideration) [*Anonym,* 2004].

Run-off dept of Pakuwojo Sub-Watershed

Result processes of calculating daily run-off depth of Pakuwojo Sub-Watershed is presented in table 6 below.

Table 6. Actual daily run-off of Pakuwojo Sub-Watershed

Mouth / Date	Daily Run-off depth (mm)												
	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Annual
1	-	-	1,30	4,39	0,1	3,49	-	5,0	2,1	-	5,07	16,16	
2	-	-	0,44	5,07	0,7	1,65	1,16	6,2	8,3	-	-	10,00	
3	-	-	3,99	1,09	4,7	1,02	-	3,5	17,0	19,82	-	6,73	
4	11,52	2,65	1,24	0,24	2,2	1,77	-	4,8	2,0	16,65	-	8,13	
5	18,51	3,44	0,57	0,90	4,9	1,28	6,38	3,5	7,2	17,72	35,10	7,49	
6	-	0,78	1,89	14,50	4,6	4,66	-	4,8	5,2	-	0,21	3,85	
7	-	4,28	2,38	50,30	13,5	4,17	-	3,5	4,0	-	4,59	7,65	
8	15,48	5,07	0,57	4,44	0,1	8,30	6,73	5,8	-	18,35	1,18	11,52	
9	-	5,07	0,09	-	0	-	0,11	8,3	7,8	17,26	0,52	6,30	
10	-	19,99	2,38	4,91	5,3	15,48	0,97	0,1	20,0	19,99	-	7,97	
11	-	-	3,85	19,40	5,8	7,34	0,00	2,1	16,5	-	47,00	8,30	
12	18,51	-	0,26	2,18	3,1	14,63	3,32	3,6	-	15,77	60,30	-	
13	9,26	-	3,58	3,05	5,1	15,33	3,52	2,3	14,6	-	3,71	8,30	
14	6,88	-	17,00	0,35	5,1	1,04	0,62	1,5	18,0	-	4,44	3,64	
15	4,28	-	2,49	0,00	0,7	0,12	0,52	0,2	-	19,82	21,30	1,89	
16	0,02	17,11	12,60	4,59	4,4	1,80	0,14	2,5	20,0	17,26	4,91	4,44	
17	3,27	-	1,02	2,25	13,5	5,07	5,07	4,9	19,7	-	20,00	0,84	
18	1,80	-	5,07	2,26	0,0	5,07	5,07	0,8	9,9	-	3,58	0,72	
19	2,83	-	1,30	4,38	0,0	1,02	0,03	4,7	-	9,26	3,58	3,71	
20	0,04	10,58	41,62	2,60	0,6	0,00	0,44	-	-	7,81	2,71	-	
21	2,87	4,51	30,10	9,03	0,0	5,07	0,02	-	-	5,62	14,00	0,04	
22	0,04	7,81	-	5,07	13,7	4,86	1,89	-	-	0,47	2,49	58,00	
23	0,04	5,89	-	4,28	2,9	0,96	3,61	-	-	1,54	17,80	1,98	
24	3,27	3,34	-	4,28	3,3	3,58	3,32	20,0	-	2,60	7,00	4,29	
25	4,44	3,07	-	5,18	1,0	34,94	3,99	20,0	17,4	2,60	1,23	5,07	
26	1,62	0,44	0,54	29,30	0,1	-	1,25	12,3	11,6	1,23	4,59	0,72	
27	5,07	29,20	17,71	4,86	2,7	0,72	2,08	19,3	20,0	0,82	3,62	0,15	
28	0,29	0,04	15,57	2,38	2,2	2,94	5,02	19,5	-	2,60	2,53	5,07	
29	1,23	0,52	0,47	-	0,1	2,57	8,19	17,4	-	1,09	5,07	3,19	
30	0,59	0,96	1,71	-	0,7	-	3,74	8,3	-	0,01	7,08	6,78	
31		0,57	3,26	-	0,6	-	4,28	-	-	30,20	-	6,93	
Total RO depth	111,8	125,3	173,0	291,2	101,4	148,9	71,5	176,6	221,3	228,5	283,6	209,9	2.142,9

Source: Computation result, 2010

Table 7 shows an overview of hydrological processes in Pakuwojo Sub-Watershed relate to rainfall-run-off relation from November 2009-December 2010. In this time period, total rainfall depth is 4062 mm and 52, 76 percent (2143, 00 mm) of total rainfall becomes surface run-off. This condition shows that the hydrological regime in the study area is bad.

Table 7. An overview of hydrological processes in Pakuwojo Sub-Watershed

Period	Watershed Area (ha)	Total Rainfall		Total Run-off		Runoff Percentage (%)
		Depth (mm)	Volume (m3)	Depth(mm)	Volume (m3)	
Nov2009-Dec2010	132,60	4.062,00	5.386.321,67	2.143,00	2.841.675,86	52,76

Source: Computation result, 2010

Estimating peak discharge and time distribution of the direct run-off

Table 8 presents the result of physical characteristic calculating of the watershed and also the result of calculating peak discharge of the study area. The calculating processes are computed using GIS analysis.

Table 8. Peak discharge calculation of Pakuwojo sub-watershed

Watershed characteristics	Calculating result	Tc($0,0ZL^{0,77}5^{-0,385}$ (minute/hour)	Tp(0,7 Tc) (hour)	Run off (Q) (mm)	Qp(0,208A.Q/Tp (m^3/s)
Area (A)	1,33 sq.km	9,20	6,44	2.143,00	91,76
Maximum length of travel (L)	1.795,12 m				
Elevation difference (H)	701,00 m				
Slope (H/L)	0,39				

Source: Computation result

Peak discharge of Pakuwojo Sub-Watershed based on unit hydrograph method developed by US-SCS is 91, 76 m^3/second.

Land cover scenarios of pakuwojo Sub-Watershed

Comparison among scenario 1, 2 and 3

From Table 9 and fig 5, it is shown that if forest, potato (land terraced) and carica papaya are applied in the same area (130, 7023 ha), each of them gives different impact on run-off yield. Forest (scenario1) can reduce significantly run-off until 48, 38 percent from actual run-off depth. In the contrary, potato (scenario 2) is enhancing run-off depth about 1, 59 percent. Carica papaya (scenario 3) also gives positive impact on reducing run-off yield in the study area. By applying carica papaya scenario, run-off depth is decrease about 24, 68 percent.

Table 9. Run-off comparison among scenario 1, 2, and 3

Month	Run-off Depth			
	Actual RO depth	Scenario 1	Scenario 2	Scenario 3
November	111,80	54,3	162,5	72,50
December	125,30	70,7	274,7	81,60
January	173,00	51,7	189	129,20
February	291,20	207,5	323,5	236,70
March	101,50	219,6	256,8	205,20
April	148,90	68,3	167,2	138,90
May	71,50	33,2	115,4	67,90
June	176,60	80,6	181,4	162,00
July	221,30	109,5	392,1	150,00
August	228,50	95,9	265,5	147,00
September	283,50	34,6	322,7	98,40
October	209,60	80,4	225,4	124,30
Total RO dept	2.143,00	1.106,30	2.876,20	1.614,20

Source: Computation result, 2010

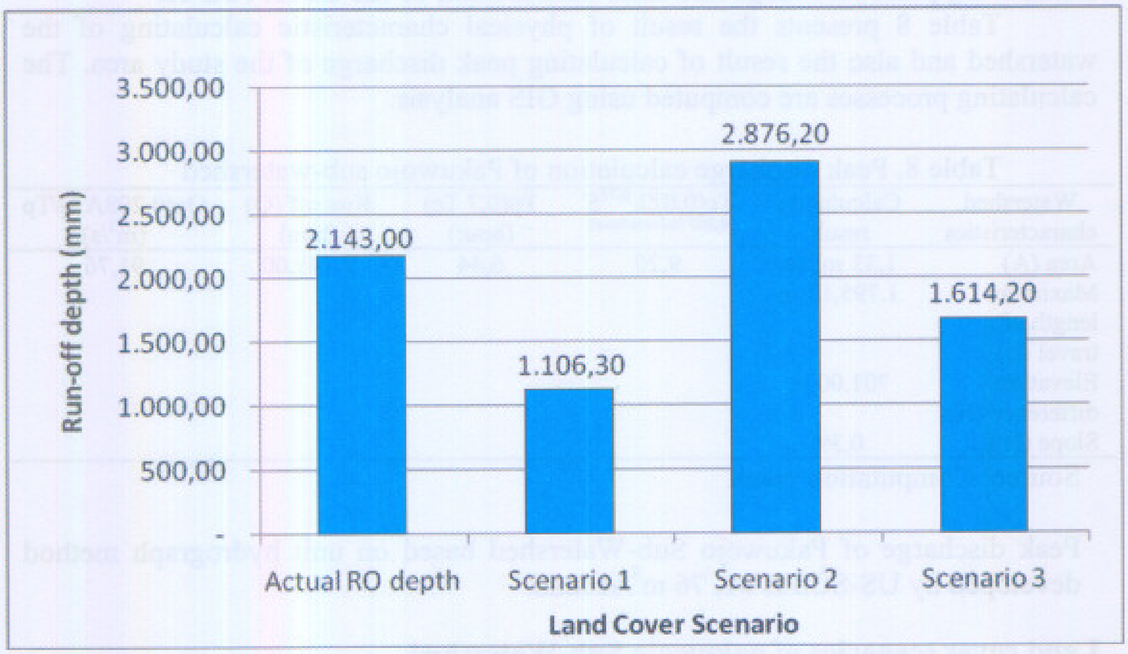

Figure 5. Comparison result among scenarios 1, 2 and 3

Land cover scenario 4

The result of run-off yield after applying scenario 4 is presented in table 10 and this land cover scenario is mapped in fig. 6

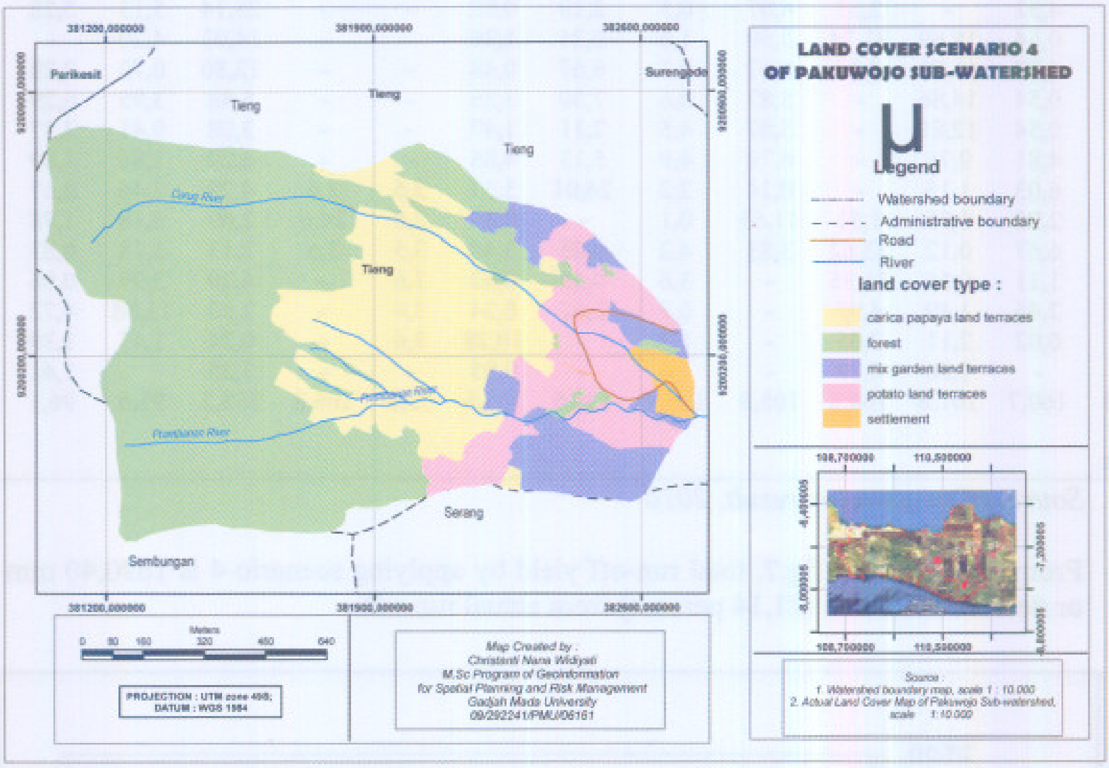

Figure 6. Land map scenario 4 of Pakuwojo Sub-Watershed

Table 10. Daily run-off computation of Scenario 4

Mouth / Date	Daily Run-off depth (mm)												
	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Annual
1	-	-	2,55	1,95	1,0	5,04	-	11,8	7,4	-	6,67	3,24	
2	-	-	1,36	6,67	0,0	2,98	2,37	1,3	1,5	-	-	8,66	
3	-	-	5,57	2,28	6,3	2,19	-	10,0	3,37,2	35,85	-	1,39	
4	26,87	0,91	0,22	0,01	0,7	3,12	-	0,6	1,4	32,92	-	1,52	
5	14,48	4,99	1,56	2,02	6,5	2,52	20,37	10,0	-	33,93	0,51	1,46	
6	-	1,86	3,26	6,61	6,2	8,00	-	1,3	9,6	-	4,80	10,41	
7	-	5,87	3,83	6,03	8,5	10,82	-	15,4	-	-	6,18	1,48	
8	31,30	6,67-	1,56	-	0,1	0,35	3,37	1,9	1,5	35,85	0,20	2,76	
9	-	-	0,69	6,51	0	-	3,77	0,6	3,6	32,92	1,49	1,35	
10	-	-	3,83	0,02	2,6	8,80	0,12	5,1	3,3-	33,50	-	1,51	
11	-	-	5,42	3,60	2,9	2,10	0,26	3,7	3,1	36,00	3,91	1,54	
12	4,48	-	1,05	9,39	4,6	10,80	4,85	2,7	3,4	32,07	11,91	-	
13	24,14	-	5,13	1,63	6,7	9,20	1,42	1,0	-	-	0,54	1,54	
14	2,89	-	0,44	0,28	6,7	0,70	1,63	0,8	3,6	-	6,03	16,22	

15	10,95	-	3,95	6,18	1,7	0,06	1,49	0,7	3,6	35,85	0,16	3,26	
16	3,23	5,78	1,49	0,35	5,6	3,15	0,04	1,9	22,8	33,50	0,65	6,03	
17	4,81	-	2,19	0,70	29,2	6,67	6,67	0,6	-	-	0,00	1,94	
18	3,15	-	6,67	1,31	3,0	6,67	6,67	-	-	-	5,13	1,78	
19	4,32	-	2,55	4,07	0,3	2,19	0,52	-	-	25,14	5,13	5,28	
20	0,54	18,69	31,74	3,99	1,6	0,34	1,36	-	-	14,93	4,20	-	
21	4,37	11,23	4,44	6,67	0,3	6,67	0,48	-	-	12,80	0,73	2,28	
22	0,54	14,86	-	5,87	8,6	7,50	3,26	-	-	5,48	3,95	6,29	
23	0,54	12,81	-	5,87	4,5	2,11	1,47	-	-	3,08	0,41	3,37	
24	4,81	9,76	-	6,78	4,9	5,13	4,85	-	-	4,29	1,86	1,89	
25	6,03	1,15	-	0,14	2,2	26,01	5,57	3,6	3,4	4,29	2,46	0,67	
26	2,95	1,36	1,51	11,65	0,1	-	2,49	2,8	24,6	2,69	6,18	1,78	
27	6,67	0,12	33,62	3,83	4,2	0,05	3,48	3,5	3,6	2,13	5,18	0,83	
28	1,11	0,56	31,35	-	3,6	4,45	6,62	3,6	-	4,29	3,99	0,06	
29	2,46	1,49	4,97	-	0,7	0,87	0,24	3,4	-	2,50	11,88	4,72	
30	0,02	2,11	3,05	-	1,7	-	10,28	3,6	-	0,24	1,43	1,39	
31	-	1,56	4,79	-	1,6	-	9,95	-	-	3,25		1,41	
Total RO depth	160,7	101,8	168,8	105,3	126,4	138,5	103,6	93,6	106,8	393,2	95,6	96,1	1.690,4

Source: Computation result, 2010

From Table 10 and fig.7, total run-off yield by applying scenario 4 is 1690,40 mm or decrease 453 mm (21,14 percent) from actual run-off.

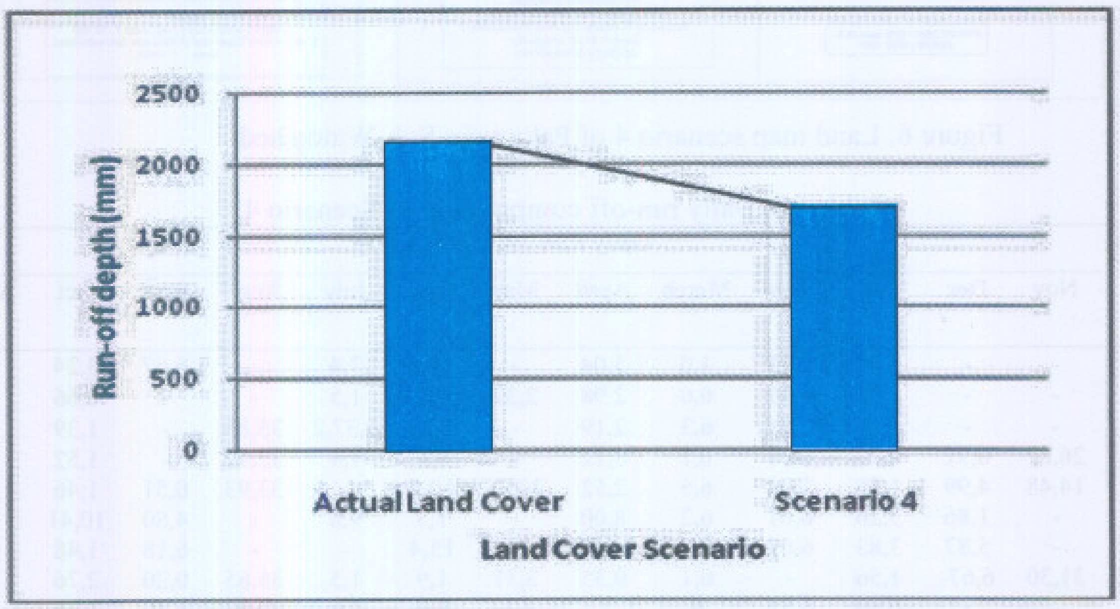

Figure 7.Comparison result between actual land cover and scenario

Validation for the application of Curve Number Method in the study area

To examine the accuracy of US-SCS Curve Number method for run-off depth estimation in the study area, model validation is done. In this study, parameter used to be validated is run-off depth itself. Estimated run-off depth and observed run-off depth are compared to reveal the difference between them. Estimated run-off depth is the result of run-off calculation using US-SCS Curve Number Method whereas observed run-off depth is run-off value result from field data analysis. SPSS functions are used to perform statistical analysis on data. Daily run-off data from 4 December 2009 until 17 March 2010 (20 data) will be used in statistical test analysis. Table 5.28 below shows the comparison between observed run-off depth and estimated run-off depth in various rainfall events. Statistical test result is presented in appendix 15.

Table 11. The comparison between observed RO depth and estimated

Nr	Date	Rainfall (mm)	Observed RO depth (mm)	Estimated RO depth (mm)
1	04-dec-09	39	5,75	2,65
2	06-Dec-09	12,3	0,38	0,78
3	16-Dec-09	5,7	1,27	17,10
4	20 Jan-10	110	37,00	41,62
5	26-Jan -10	13,7	2,79	0,54
6	28-Jan-10	8,9	5,45	15,57
7	12-Feb-10	6,9	1,81	2,18
8	12-Feb-10	12,6	0,10	3,05
9	14-Feb-10	13,2	0,51	0,35
10	15-Feb-10	5,7	4,90	0,00
11	17-Feb-10	34,5	2,07	2,25
12	18-Feb-10	37,5	2,48	2,26
13	19-Feb-10	41,4	4,07	4,38
14	21-Feb-10	52,8	7,63	9,03
15	01-Mar-10	16,2	0,67	0,20
16	02-Mar-10	29,7	1,04	0,70
17	04-Mar-10	37,2	3,61	2,20
18	07-Mar-10	66	10,78	13,50
19	08-Mar-10	24,6	0,87	0,10
20	10-Mar-10	47,4	6,34	5,30

Sources: computation Result

Statistical test result between those two parameters reveals that t_{obs} is less than t_{cr} in the level of significance 5 percent. The value of t obtained from statistical test is 0,059, while t Table is 2, 0244. This means that there are no significant differences between those two samples (observed run-off depth and estimated run-off depth). This can be concluded that US-SCS Curve Number method can be applied to estimate direct run-off depth in the study area.

CONCLUSIONS

1. Before the year of 1980, the face of Dieng plateau area, including Pakuwojo sub-Watershed, are mostly covered by forest coverage. Based on the result of field ground check, more than 50 percent land use is dominated by vegetables plantation. The forest coverage left in study area (36, 76 percent) is state land area. Two types of land treatment or practices are done by local people to prevent their land from erosion which could be triggered by high surface run-off. Those two types of land treatment or practices are land terraces and rockwall terraces.
2. Run-off estimation of Pakuwojo Sub-Watershed result from US-SCS Curve Number method application is 2143, 00 mm. This means that 52, 76 percent rainfall felt in the area becomes surface run-off. This shows that the hydrological condition of the area is bad. Peak discharge estimation is also conducted using equations developed by US-SCS. Additional parameter to calculate peak discharge using this method is physical characteristics of the watershed (area, the longest stream, and slope). Peak discharge result from the calculation is 91, 76 m^3/second.
3. Land cover scenarios developed in the study area show that (1) forest coverage can reduce dramatically surface run-off until 48,38 percent from actual run-off (from 2143,00 mm to 1106,20 mm), (2) hydrologic ally, carica papaya is better than potato. Applying carica papaya can reduce run-off yield 24, 6 percent while potato increases run-off 1, 59 percent. Alternative land use is applied in fourth scenario. By applying this scenario, run-off is decrease 21, 14 percent from actual run-off depth.
4. Statistical test is done to reveal the differences between estimated run-off depth and observed run-off depth. Statistical test reveals that there are no differences between observed run-off depth and estimated run-off dept in level of significance 5 percent. It can be concluded that US-SCS Curve Number method is appropriate to estimate run-off depth in the study area.

RECOMMENDATIONS

Forest is the best coverage for reducing run-off yield. Applying forest scenario in the study area can reduce more than 50 percent run-off. Since the bad hydrological condition is caused by the domination of vegetable plantation, especially potato, alternative commodity which gives better impact to improve hydrological regime in the study area is needed. Model scenarios applied in the study area shows that among existing land cover, carica papaya is the most appropriate land cover which can substitute potato taps the main commodity. Hydrologic ally, carica papaya is better than potato.

US-SCS Curve Number method is a simple method to estimate run-off depth in ungauge watershed. This study reveals that this method is appropriate to be used for run-off depth estimation in the study area, and also in other places in Indonesian country which have similar physical condition with study area.

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